Report No. 052008/3

WORKPLAN FOR STORAGE COVER TEST PLOT STUDY, QUESTA TAILINGS FACILITY, NEW MEXICO

(TAILINGS FACILITY CLOSEOUT PLAN PROGRAM TASK A2)

Prepared for

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1 INTRODUCTION

1.1 Terms of References

On May 1 1998, Molycorp submitted a Revised Closure Plan for the Questa Tailings Facility to the NMED as required under modifications to the DP 933 for the tailings impoundment. Provisions were made in the closure plan to conduct a "Storage Cover Test Plot Study" upon approval of this closeout plan by the NMED (see section 4.3.4.2 of RGC Report 052004/1 entitled "Questa Tailings Facility Revised Closure Plan"). In a response letter by the NMED (GWQB) dated April 5 1999 the NMED requested additional information on the Revised Closure Plan, among others a detailed work plan for this Storage Cover Test Plot Study.

On July 29, 1999 Molycorp responded to the NMED letter providing further details on the proposed Storage Cover Test Plot Study and proposing to submit a work plan on the test plot study within 30 days of receiving comments back from the NMED.

On November 15, 1999 Molycorp submitted a schedule to the Mining and Minerals Division (MMD) of the Energy, Minerals, and Resources Department of New Mexico detailing milestones and deliverables in support of a time extension application for the Questa Mine, New Mexico, under Permit No. TA001RE. This schedule outlines the supporting studies and reports as well as the public review program required for approval of the Closeout Plan for the Questa Tailings Facility by December 29, 2000 (Appendix A). Molycorp's application for the time extension for approval of a closeout plan for the Questa Mine and Tailings Facility was approved by the MMD on December 30, 1999.

The submitted schedule provides for a work plan of the Storage Cover Test Plot Study (Task A.2 of Work Schedule for Tailings Facility, see Table A2 of Appendix A, respectively) to be submitted to the MMD by January 31, 2000. The present workplan, originally requested by the NMED and later included in the schedule of studies and deliverables for the Closeout Plan, has been prepared on behalf of Molycorp to satisfy both the requirements of MMD and NMED.

1.2 Rationale and Objectives of Tailings Cover Test Plot Study

In the Closeout Plan for the Questa Tailings Facility, submitted May 1st 1998, Molycorp proposed to place a 9" thick soil layer over the tailings after final closure of the facility. This soil layer would prevent erosion of the tailings, provide a growth medium for re-vegetation and, in conjunction with the underlying tailings, represent a water storage (or "store-and-release") cover that would reduce infiltration into the deeper tailings profile. Preliminary cover performance modeling suggested that a 9" thick soil layer would reduce the cover flux into the deeper tailings to about 3-8% of total precipitation for an average precipitation year. Seepage modeling suggested that such low seepage fluxes at the base of the tailings would not result in contaminant concentrations to exceed New Mexico Water Quality Standards.

A storage cover test plot study is proposed to collect site-specific data of cover performance to be used for the final design of the water storage cover to be placed after decommissioning of the Questa tailings facility. The test plot study has been designed to meet the following objectives:

- measure climatic conditions at the site;
- measure in-situ material properties (characteristic curves); and
- calibrate a soil-atmosphere model in order to predict net infiltration.

It is important to recognise that the primary objective of the test plot study is <u>not</u> to measure cover fluxes per se but instead, to calibrate the soil-atmosphere model for known (measured) boundary conditions. The ultimate goal is to use the calibrated soil-atmosphere model to predict with a high degree of confidence the performance of the storage cover for conditions relevant to final closure (i.e. deep, unsaturated tailings profile; mature vegetation; range of climatic conditions). These final closure conditions cannot, of themselves, be duplicated in a field trial of only a few years, but instead have to be simulated.

2 GENERAL DESIGN OF STORAGE COVER TEST PLOT STUDY

The general design of the storage cover test plot study was initially outlined in the Revised Closure Plan for the Questa Tailings Facility (see section 4.3.4.2 in RGC Report 052004/1) and is repeated here for completeness.

A total of three cover test plots will be instrumented to measure the performance of three different combinations of cover thickness and vegetation development (see Figure 1):

Cover Test Plot #1: old 9" thick alluvial cover with mature shrub vegetation overlying in-situ sandy tailings (very deep tailings profile);

Cover Test Plot #2: 9" thick alluvial cover with no vegetation overlying back-filled sandy tailings (~2.5 m deep tailings profile); and

Cover Test Plot #3: 18" thick alluvial cover with no vegetation overlying back-filled sandy tailings (~2.5 m deep tailings profile).

Note that the thickness of the alluvial cover layer in cover test plot #3 has been reduced (from 36" originally proposed in RGC Report 052004/1) to 18" as requested by the NMED in their April 5, 1999 letter.

Field performance of each test plot will be monitored by a system designed to measure climate conditions, changes in moisture conditions within the storage cover and in the underlying tailings, and net infiltration to the underlying tailings. The monitoring system includes (c. Figure 1):

- a full weather station (including a Bowen Ratio System) to measure precipitation, various parameters to determine potential evaporation and actual evapotranspiration;
- soil matrix suction sensors and soil water content sensors to measure soil water storage and moisture movement; and
- piezometers (in test plots #2 and #3 only) to measure net percolation directly.

Cover test plot #1 is most representative of post-closure steady-state conditions, i.e. with a mature vegetation established on the alluvial cover which overlies undisturbed hydraulically placed tailings, i.e. the 'natural' condition. This cover test plot is designed as an open system, i.e. the monitoring instrumentation will be installed into the existing cover and tailings profile (without prior excavation). Any excavation of the cover and tailings profile would destroy the root system of the vegetation, which is considered a vital component of this cover system, as well as the 'natural' soil structure and density of the hydraulically placed tailings. Cover test plot #1 will be used to calibrate the soil-atmosphere model against measured changes in soil moisture and soil suction over time. The calibrated soil-atmosphere model of cover test plot #1 will be used to predict the net flux through a mature cover system for post-closure steady-state conditions.

Cover test plots #2 and #3 represent closed systems or "lysimeter plots", in which the test plot is lined to capture all moisture entering the cover-tailings system (Figure 1). This approach has the advantage that the critical performance parameter, i.e. net flux at the base of the cover system, can be measured directly. However, the lysimeter design will differ from in-situ conditions in two ways. First, the properties of the mechanically placed, back-filled tailings may differ from those of the in-situ tailings. Second, a water table is introduced at the base of the lysimeter plot, which will influence the soil moisture profile in the overlying cover system. The lysimeter approach is conservative in a sense that both of these factors tend to result in greater net fluxes through the cover.

Cover test plots #2 and #3 will be used to calibrate the soil-atmosphere model against measured net fluxes. Note that the (known) effects of the lysimeter design (e.g. shallow depth of tailings) can be taken into account during model calibration. These cover test plots will be kept free of vegetation for two years in order to allow the calibration of the soil-atmosphere model without the complexity of root transpiration (i.e. evaporation is the only mechanism of soil water removal from the lysimeter plot). In year three, cover test plots #2 and #3 will be vegetated according to the methods outlined in the re-vegetation plan (see section 4.3 in RGC Report 052004/1). The observed net fluxes in cover test plots #2 and #3, in conjunction with model predictions for a deeper tailings profile (test plot #1), will allow an evaluation of the effect of cover thickness on cover performance immediately after closure. A comparison of the model predictions for test plots #1 and #2 will demonstrate the relative importance of evaporation versus evapotranspiration in cover performance.

The three cover test plots will be set up in the Section 35 Tailings Area located between Dam 1 and Dam 1C (Figure 2). This location has been selected for three reasons. Firstly, this tailings area has been covered for almost 25 years, which allowed the establishment of a mature shrub vegetation on the cover material. In other words, the conditions encountered here represent very closely those anticipated for post-closure steady-state conditions. (net infiltration minimized by evapotranspiration of a mature shrub vegetation). Secondly, the tailings in this area consist of coarse tailings, which are expected to allow greater net infiltration than fine tailings. The coarse tailings also represent the predominant size fraction in the various tailings impoundments. Hence, the study of cover performance on sandy tailings will yield conservative and most representative estimates of net infiltration. Thirdly, no future tailings discharge is planned in this tailings area providing stable test and hence model boundary conditions into the future, a deep unsaturated tailings profile, and continued access to the site.

The detailed work plan for the cover test plot study is provided in the following section.

3 WORK PLAN

The following work plan outlines the scope of work for the storage cover test plot covering the period spring 2000 to summer 2003. In general, this work plan follows the scope of work outlined in the Revised Closeout Plan submitted on May 1, 1998. However, some changes/additions have been made to the original design to accommodate requests made by the NMED (in their letter of April 5, 1999). The original time schedule has also been condensed to provide (preliminary) results by the summer of 2001.

Task 1 Design & Construction

This task summarises the design and construction of the test plots and met station. For details on the proposed monitoring equipment the reader is referred to Appendix B of the Revised Closure Plan (RGC Report 052004/1).

Task 1.1 Lysimeter Design

Two conceptual designs are being considered for construction of the lysimeter plots (Figure 3). In option 1, the lysimeters would be installed by excavating into the existing tailings with a backhoe to create an inverted truncated pyramid excavation with 1.5H:1V side slopes (Figure 3). The sloping side walls are dictated by the need for safety during construction and cost. The walls would be lined with a textured HDPE product to the elevation of the cover surface creating a closed system for each lysimeter. In this option, the lysimeter would be approximately 2.5m deep and have a foot print area of approximately 7.5m x 7.5m at the bottom and approximately 15m x 15m at the surface. In this design option, a significant portion of the lysimeter plot has a tailings thickness less than the design depth of 2.5m thus introducing 2D flow effects. The HDPE liner could be folded back near the tailings surface (within the cover layer) to prevent any atmospheric fluxes in those areas of the lysimeter plot, which lie outside of the basal foot print (see Figure 3).

In option 2, a circular, pre-cast manhole unit or a circular tank would be lowered into the excavation to provide shoring and, at the same time, provide an impermeable wall for the lysimeter plot (see Option 2 in Figure 3). The manhole unit or tank could be made of concrete, steel or reinforced fiberglass, or pre-cast thick wall HDPE. The inside walls of the manhole unit or tank would have to be lined if the material is chemically active and could possible influence tailings pore water quality (i.e. concrete or steel). Option 2 has the advantage that there are no two-dimensional flow effects due to the vertical walls of the lysimeter plots. This way, the dimensions of the lysimeter plot can be kept considerably smaller. The diameter of such a circular lysimeter plot is more controlled by logistics during construction than by boundary effects. A diameter of about 3m would probably be sufficient to allow easy handling of tailings material during back-filling as well as instrument installation within the lysimeter.

Two-dimensional (2-D) saturated-unsaturated modeling will be done prior to finalizing the design of the field lysimeters. The parameters to be finalized as part of this modeling program are:

- geometry and dimensions of lysimeter plots #2 and #3;

- required thickness of tailings below cover layer;
- thickness and type of bottom drain layer; and
- vertical spacing of soil suction and moisture content sensors.

The results of the design modeling for various test plot configurations will be submitted to the agencies (NMED and MMD) for review. Based on these modeling results as well as material availability, local safety regulations, and cost, a final test plot design will be selected and submitted to the agencies (MMD and NME) for approval.

Task 1.2 Construction and Instrumentation of Test Plots

Figure 1 shows the proposed instrumentation for the three test plots. Details on the proposed monitoring equipment (purpose and technical specification) are summarized in the Revised Closeout Plan for the Questa tailings facility (see Appendix B of RGC Report 052004/1) and will not be repeated here.

For test plot #1 an area of 5m by 5m with a mix of grass and bush vegetation (deemed representative of the vegetative cover of the reclaimed tailings in this area) will be staked out. An access ditch will be excavated along one side of the test plot to a depth of approximately 3 m. The ditch will provide access to the reclaimed tailings profile for lateral installation of the suction-temperature sensors. Temporary retaining, or bracing walls will be constructed from plywood and lumber on all sides of the excavation to ensure the profile can be accessed safely. The suction-temperature sensors will be installed into a vertical face of the tailings profile towards the centre of the test plot. A 5 cm diameter pilot hole will be created laterally for each sensor to a distance of approximately 2 m from the exposed tailings face using a hand auger. Pilot tubing will be placed in the lateral pilot hole while drilling to ensure the hole does not collapse. A "T" bar hand drill with a 2.5 m extension and a drill of slightly smaller diameter than the suction-temperature sensor will be used to create a small hole approximately 25 cm beyond the end of the lateral 5 cm diameter pilot hole. The suction-temperature sensor will be pushed into the slightly undersized drill hole using specifically designed installation tools to ensure good tailings/sensor contact.

The procedure outlined above will be repeated for installation of each of the 10 suction-temperature sensors and the lead wires extended up to the surface for connection to the data acquisition system (DAS). The DAS will be commissioned and all sensors will be tested to ensure the system is functioning properly. The small diameter hole and the lateral pilot hole will be backfilled once operation of the system has been verified. The holes will be backfilled by hand using specifically designed tools as the pilot tubing is removed. The temporary bracing walls will be removed as the access ditch is backfilled and QA/QC testing is being conducted during backfilling.

Access to the tailings profile by the volumetric water content sensors will be provided by installation of a vertical PVC access tube (Figure 1). The sensors are designed by the manufacturer for installation into the PVC access tubes provided by the supplier. A 5 cm diameter vertical hole will be created to a depth of 2.5 m by hand auguring or using a small gas powered two-man auger. The vertical holes will be located 0.5 m to 1 m laterally from the (laterally installed) profile of suction-temperature sensors. The vertical drill hole will be slightly undersized and the PVC access tube pushed in after completion of the vertical hole to the required depth. It is anticipated the tailings will not slough into the hole during or subsequent to drilling due to the unsaturated condition of the material. The PVC access tube will be sealed at the base to ensure moisture does not enter the access tube from within the tailings mass.

The volumetric water content sensors will be connected to a rail (supplied by the manufacturer) and the lead wires to create a single probe. The probe will be inserted into the access tube and the lead wires connected to the data acquisition system after capping the access tube with a specifically designed PVC cap. The volumetric water content sensors will be placed on the rail such that the measurement depths will correspond to the suction-temperature sensors. The position of the volumetric water content sensors on the rail can be changed by a trained technician.

For test plots # 2 and #3 two areas (minimum size 12m by 12m) will be staked out on either side of test plot #1 at a distance of about 50m (Figure 2). First, the in-situ density and moisture content of the upper 8 inches (alluvial soil cover) will be determined using a nuclear densometer probe (5-10 tests). In addition, two sand cone tests (12" dia) will be performed to provide independent estimates of in-situ density and moisture content. Once the tests are completed the vegetation will be carefully removed (cutting roots) and the interim cover soils removed and stockpiled under a tarp. The in-situ density and moisture content of the freshly exposed tailings (upper 8-10 inches) will be determined using the nuclear densometer (5 tests) and a smaller (6" dia) sand cone apparatus (2 tests).

The process of excavation (in layers of 1ft) and geotechnical characterization (in-situ density and moisture content) will be repeated 8 times to a total depth of 2.5m into the tailings. The tailings of each layer are stockpiled separately (for later backfilling) and covered under a tarp to minimize any changes in moisture content. Representative grab samples of each layer will be taken for potential geotechnical testing in the laboratory (hydraulic permeability, moisture retention curve).

Depending on the final design of the lysimeter plots either HDPE liner will be laid out directly onto the base of the excavation (Option 1) or a lined lysimeter vessel (Option 2) will be lowered into the excavation. A stand pipe piezometers will be placed within each lysimeter and held in position while uniform filter sand will be carefully backfilled into the base of the lysimeter (depth of fill sand and grading to be finalized by 2D design modeling).

Once the base of filter sand is completed the tailings will be backfilled in 1ft (0.3m) layers. To the extent practical the tailings will be re-compacted to the same in-situ density and moisture conditions as were determined during excavation (i.e. average conditions encountered during excavations for any given layer). At the appropriate depths the suction-temperature sensors will be laid out and carefully buried in the backfilled tailings 0.5 m to 1 m laterally from the stand pipe piezometers. The lead wires will be run horizontally to the outer edge of the lysimeter, gathered, tied, and brought to the surface for subsequent connection to the DAS. The response of the sensor will be tested following placement and compaction of the overlying lift to ensure the sensor was not damaged during compaction. Additional sensors will be available to replace any sensors damaged during construction. The area immediately around the piezometers will be compacted by hand to achieve a good seal. In addition, annulus bypass rings will be installed (predominately near the surface) along the piezometer casing to prevent preferential channeling

Once the tailings have been backfilled to surface the alluvial cover material will be placed in lifts of 9 inches (i.e. 1 lift for test plot #2 and 2 lifts for test plot #3). Again an attempt will be made to match the in-situ density and moisture content measured in the cover material prior to excavation. The foot print area of the alluvial cover placed on top of the lysimeter will be significantly greater than that of the lysimeter (about 3 times in diameter, see Figure 3). The cover layer will be constructed from representative alluvial cover material taken from a local (small) borrow pit. Grain size analyses will be completed in the field to ensure that the cover material used is similar to the cover material present at the site. Grab samples will be retained for future analyses in the laboratory.

In order to eliminate any potential surface runoff (or run-on) within the test plot area the surface will be levelled and a skirt (made of plastic or other inert material) pushed into the surface (extending about ~2" above ground surface) surrounding the foot print area of the lysimeter.

The construction and instrumentation of the test plots will be supervised by a geotechnical engineer familiar with the equipment and installation procedures. A photo record will be taken of all pertinent steps in the construction.

Task 1.3 Set-up of Met Station

A fully automated meteorological station will be constructed at the test plot area (Figure 2) to properly evaluate atmospheric boundary conditions for future numerical model calibration. The weather station will consist of an all-weather rain gauge, relative humidity/temperature probe, wind sensor, and radiometer (see Appendix B of RGC Report 052004/1 for details). The sensors will be mounted on a 30 foot tower anchored to the surface using a small concrete pad and guy wires. The meteorological station will have a stand alone data acquisition system and will be powered by solar panels. The weather station will be commissioned prior to or during construction of the test plots.

A fully automated Bowen Ratio System (BRS) will be used for measuring actual evapotranspiration (see Appendix B of RGC Report 052004/1 for details). The Bowen Ratio is the ratio of sensible heat loss from the surface to the atmosphere and the energy utilized for evaporation. The latter term is calculated based on measurements of net radiation, total soil heat flux, and the gradient of temperature and vapour pressure above the surface. The actual evapotranspiration rates are highly site specific. The Bowen Ratio System is portable and can be moved among the three test plots (and to other areas of the tailings) to obtain representative data for different sites.

Task 1.4 QA/QC Procedures

Each suction-temperature sensor will be calibrated in the laboratory prior to field installation. The laboratory calibration procedure achieves two objectives. First, each sensor will be checked to ensure it is operating properly. Second, a calibration curve relating sensor output to applied matric suction will be developed. Matric suction, like temperature, is a stress state variable. Hence, the sensor does not require calibration to field conditions.

The response of the volumetric water content sensors will be influenced by field conditions such as texture, pore-water quality, and the mineralogy of the tailings. Hence, each sensor will require field calibration in order to obtain quantitative field volumetric water content measurements. The following outlines the field calibration methodology.

A series of six 45 gallon drums will be prepared for calibration of the sensors while at the site. The drums will likely be cut down to reduce the tailings material required to fill each drum. The first drum will have a PVC access tube standing in air (i.e. the drum is not backfilled) and the response of the sensor measured to represent a "dry" condition and one extreme of the calibration curve. The second drum will be filled with de-ionized and distilled water, with the PVC access tube placed in the water, and the response of the sensor measured to represent a "wet" condition and the other extreme of the calibration curve. The four remaining access tubes will be backfilled with tailings prepared to represent the range of moisture and density conditions measured during excavation and construction of the test plots. The PVC access tube will be installed using the same procedure outlined in Task 1.2 after the drums are backfilled with the tailings. The response of each sensor will be recorded in the four different conditions. The six calibration points will be used to develop field calibration curves for each sensor. In addition, the *in situ* density and moisture measurements obtained during excavation and construction of the test plots can also be used to develop the field calibration curve for each sensor once the sensors have been installed in the access tubes and a measurement obtained.

Task 1.5 As-Built Report

An as-built report for installation of the field monitoring equipment will be submitted to the agencies (NMED and MMD) within 60 days of installation. The as-built report will include as-built drawings of the test plots, all results of equipment calibration and field testing and a a photo log of field construction.

Task 2 Field Performance Monitoring

Task 2.1 Climate Monitoring

The climate variables (temperature, relative humidity, and wind speed) will be measured in 1 minute intervals. The average hourly values will be recorded which will represent an average of 60 measurements. The average daily values for the same parameters will also be recorded which to represent an average of 1440 measurements. Finally, the maximum and minimum daily values, as well as the time they occurred, for these three parameters will be recorded based on the 1440 measurements. Precipitation (rain or snow) will be recorded on an event basis using an all-weather tipping bucket rain gauge.

Net radiation will be measured in W/m^2 in 1 minute intervals. Each value will be multiplied by the time elapsed (i.e. 60 seconds) and added to the previous value to record the total net radiation measured over a 24 hour period in MJ/m^2.

The data from the weather station will be downloaded initially after 1 month and thereafter every three months. The operation of the weather station will be checked at least once a month for the first year and quarterly thereafter. The weather station will be operated as long as the test plot study is on-going (at least 3 years).

The intense climate monitoring at the (fixed) weather station will be augmented by less detailed climate monitoring at other locations including:

- initial survey of climate variability across the tailings facility;
- "mini" weather stations (rain gauges and wind monitor) at selected locations on the tailings;
- 12 point snow course during snow melt; and
- Bowen ratio system measurements at various locations.

Initial Survey of Climate Variability

Manual surveys of net radiation, temperature and wind speed & direction will be done on a grid covering the entire tailings impoundment on a few selected days to provide a comparison to the test site for the purpose of scaling. Based on this survey locations will be selected for additional "mini" weather stations

"Mini" Weather Stations

A total of three additional mini weather stations, consisting of tipping bucket rain gauges with event data loggers will be installed across the tailings facility. A wind monitor with data logger will be mounted at one of these locations (exposed on the top of the tailings). Precipitation and wind will be recorded for one full year. The data will be compared to the precipitation and wind data from the met stations to assess the variability in these climate variables across the tailings facility in general and between the top of the tailings and the test plot site in particular.

Snow Course

Snow surveys will be carried out using a minimum of 12 stations across the tailings facility (including 3 stations in vicinity of the test site) to measure snow depth and water equivalency. Snow surveys will be taken bi-monthly during the winter months and weekly during snowmelt for at least two full seasons.

Bowen Ratio System Measurements

Bowen ratio system (BRS) measurements will be carried out and recorded using an automatic data logging system. The BRS system is portable and will be moved in regular intervals between the three test plots and on occasion to other locations across the tailings facility to determine the variability in actual evapotranspiration. BRS measurements will be carried out for at least one full year.

The results of this additional climate monitoring will be used to extrapolate the results of the cover test plot study to the climatic conditions of the exposed tailings (if they differ significantly) by way of modeling (see below).

Task 2.2 Cover Performance Monitoring

The test plot parameters (soil temperature, suction, water content, and water level) will be recorded every 2 hours using a data acquisition system powered by a rechargeable battery-solar panel system. The 2-hour recording interval can be extended to every 6 or 12 hours following a review of the first few months of data. The monitoring data will be downloaded initially after 1 month and thereafter every three months. The operation of the various monitoring instruments and data acquisition system will be checked at least once a month for the first year and quarterly thereafter.

Water levels in the piezometers will be checked at least once a month to provide a control to the water level readings recorded with the pressure transducer. The free pore water accumulating at the base of the lysimeters (test plots #2 and #3) will be pumped out of the lysimeter every three months (for water quality monitoring, see below) or whenever the water level is close to the top of the filter sand (whichever comes first). This way an unsaturated moisture profile is maintained within the instrumented tailings at all times.

The cover test plots will be monitored for at least three years (and optionally until closure) to observe the change in net infiltration with a maturing cover vegetation. However, the emphasis and frequency of monitoring may change over time (e.g. monitoring intervals may be increased and site visits reduced during monitoring years 2 and 3).

In their latest response (latter dated April 5, 1999) the NMED requested that biointrusion into the test plots be controlled. However, it is unclear to Molycorp how bio-intrusion could be "controlled". Clearly, root penetration is desired and should not be controlled. The activity of gophers and particular ants is difficult to control in practice. All available information on storage cover performance suggests that burrow holes (unless covering a large percent of total surface area) do not significantly effect cover fluxes (O'Kane pers. comm.). In addition, control of bio-intrusion after final closure is not feasible. Therefore, Molycorp proposes to not interfere with bio-intrusion as a natural process in the test plot study. The empirical rates of cover flux observed during the study would then provide a conservative (high) estimate of cover flux. In case gophers will not burrow in the cover test plots Molycorp proposes to artificially dig holes into the cover test plots (after say 2 years of monitoring) to a depth typically observed at the site to evaluate the effect of such holes on cover performance.

Task 2.3 Water Quality Monitoring

Water collecting at the base of the test plots (#2 and #3) will be pumped from the piezometers every three months (provided the cover flux is sufficient to allow sampling). Field parameters will be determined (pH, electrical conductance, temperature) on site. Next the sample will be filtered and shipped to an accredited laboratory for analysis of the following constituents (requested by NMED): carbonate, bicarbonate, total alkalinity, chloride, fluoride, total dissolved solids, sulfate, silver, aluminum, arsenic, barium, calcium, cadmium, cobalt, chromium, copper, iron, nitrate, mercury, potassium, magnesium, manganese, molybdenum, sodium, nickel, lead, selenium and zinc.

The water quality monitoring will be continued as long as the test plot study is on-going (at least 3 years).

Task 2.4 Inspection & Maintenance

Procedures for inspection and maintenance of the field performance monitoring system and the Bowen Ratio System are provided in Appendix B and Appendix C, respectively. The results of the inspections and any maintenance conducted will be reported in the quarterly monitoring reports during the first year of monitoring and semi-annual reports thereafter (see Task 2.5).

Task 2.5 Monitoring Reports

The monitoring results for climate, cover performance, and water quality will be summarized in quarterly monitoring reports for the first year and semi-annually thereafter and submitted to the government agencies (NMED and MMD). These reports will also include the results of the quarterly inspection/maintenance site visit.

Task 3 Cover Performance Modeling

As outlined earlier the primary objective of the cover test plot study is the calibration of a soil-atmosphere model. It is proposed to use the finite element code SOILCOVER, developed by the University of Saskatchewan, for interpretation of the cover test plot results (see RGC Report 052004/1 for details).

Task 3.1 Preliminary Modeling

After six months of monitoring an initial model calibration will be performed for each test plot in order to determine, whether the cover test plots have stabilized (i.e. recovered from initial disturbance during construction). At this time any potential problems with the instrumentation and/or the cover test plot design may also be rectified.

Using these preliminary results the cover performance of a 9" and 18" thick alluvial cover will be re-evaluated for an average-wet (1984) and a very wet (1993) year. The results of this preliminary modeling (done with SOILCOVER) will be summarized in a report and submitted to the agencies (NMED and MMD).

Task 3.2 Model Calibration & Long-Term Performance Modeling

Final model calibration will be performed once one full year of monitoring data are available past the initial stabilization period (summer 2001 at the earliest). The calibrated model will then be used to predict the net fluxes through the various cover alternatives for long-term closure conditions (using a 5 year "average" period and a 5 year "very wet" period).

The metereological input data for this predictive modeling will be synthesized by comparing the long-term records available for Cerro and the short-term records gathered during the test plot study (at the test plot site and across the tailings facility).

Task 3.3 Verification of Calibrated Soil Cover Model

The monitoring data collected during years 2 and 3 will be used to verify, and if necessary, update the calibrated soil-atmosphere model. The calibrated soil-atmosphere model will be used to predict the soil moisture movement (and net infiltration) in the three cover test plots using the climate data collected during this extended observation period. The accuracy of the calibrated soil-atmosphere model will be judged by its ability to match the observed cover responses.

If the fit between predicted and observed cover performance is deemed unacceptable, the soil-atmosphere model will be updated to obtain a better fit. In this case the net fluxes through the various cover alternatives for long-term closure conditions (using a 5 year "average" period and a 5 year "very wet" period) will be re-run using the updated model.

The results of the verification modeling (and updated cover performance analysis, if required) will be summarized in a report and submitted to the agencies (NMED and MMD).

4 SCHEDULE AND DELIVERABLES

The schedule for the proposed work plan is shown in Table 1. The deliverables and dates of submission are summarized in Table 2.

Table 1. Schedule for Tasks of Storage Cover Test Plot Study, Questa Tailings Facility.

	1st Quarter 2000	2nd Quarter 200	3rd Quarter 2000	4th Quarter 2000	1st Quarter 2001	2nd Quarter 200	3rd Quarter 2001	4th Quarter 2001	1st Half 2002	2nd Half 2002	1st Half 2003	2nd Half 2003	
Task 1 Design & Construction													
Task 1.1 Lysimeter Design													
Task 1.2 Construction & Instrumentation of Test Plots													
Task 1.3 Set-up of Met Station													
Task 1.4 QA/QC procedures													
Task 1.5 As-built Report		July 31, 2000											
Task 2 Field Performance Monitoring													
Task 2.1 Climate Monitoring												?	
Task 2.2 Cover Performance Monitoring												?	
Task 2.3 Water Quality Monitoring												?	
Task 2.4 Inspection & Maintenance													
Task 2.5 Monitoring Reports													
Task 3 Cover Performance Modeling													
Task 3.1 Preliminary Modeling				Nov 30, 2000									
Task 3.2 Model Calibration and Cover Performance Modeling							July 31, 2001						
Task 3.3 Verificationa of Soil-Atmosphere Model												July 2003	

Code:

■ Report

Note: Report submittal dates asumme test plot construction can be completed by May 31 2000

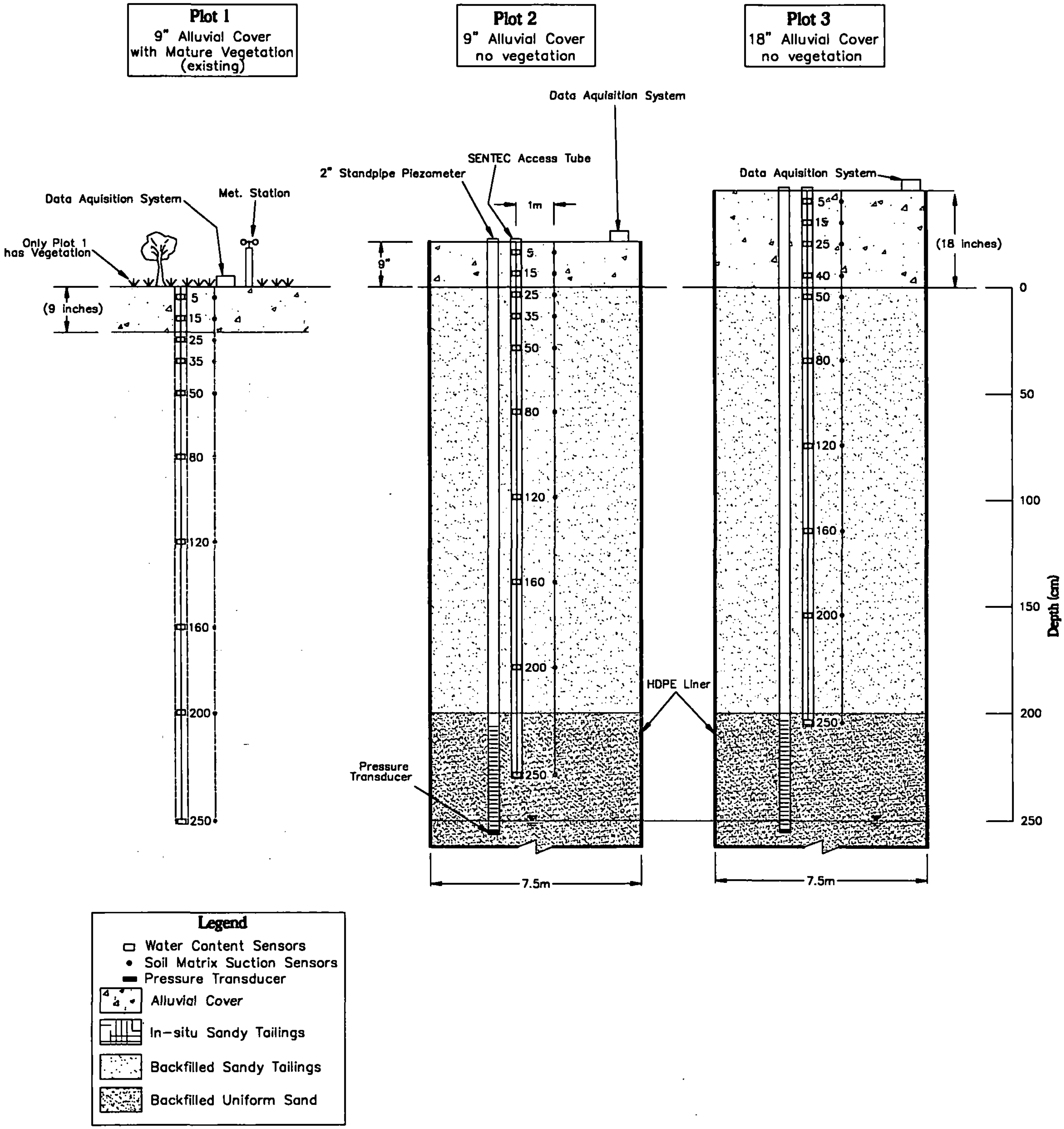
Table 2. *Deliverables for Tailings Storage Cover Test Plot Study.*

Deliverable	**Date of Submission**[1]
As-Built Report for Construction of Test Plots and Set-up of Met Station	July 31, 2000
Interim Report on Cover Test Plot Study (w/ preliminary modeling results)	November 30, 2000
1st Year Report on Cover Test Plot Study (w/ cover performance modeling)	July 31, 2001
3rd Year Report on Cover Test Plot Study (w/ cover performance modeling)	July 2003
Quarterly Monitoring Reports (4 in total)	September 2000 – September 2001
Semi-annual Monitoring Reports (4 in total)	March 2002 – September 2003

Notes:

[1] all submission dates are based on the assumption that test plot construction will be completed by the end of May 2000; delays in construction of the test plots will result in respective postponement of these submission dates

Figures

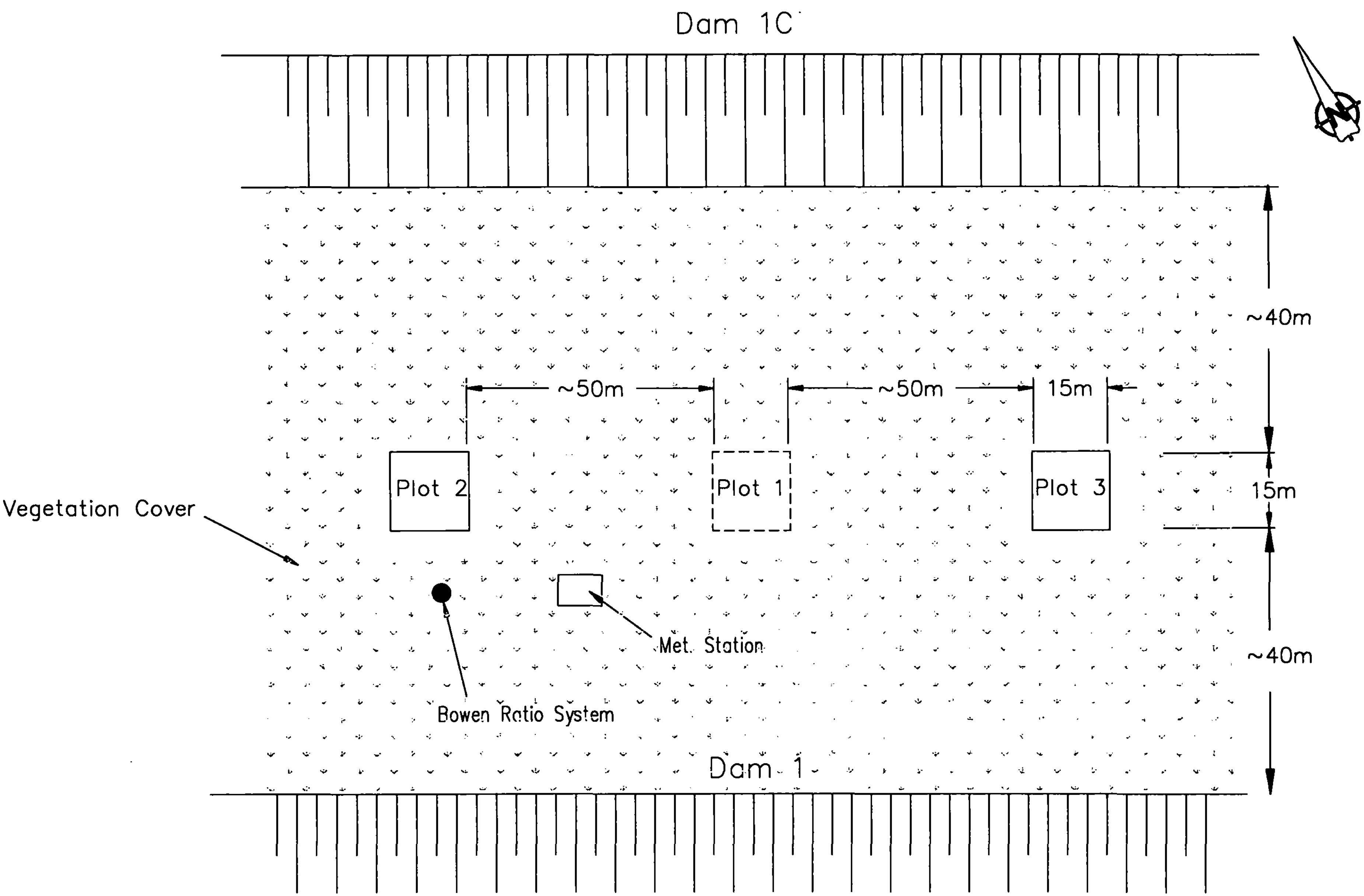


CLIENT:	MOLYCORP, INC.
PROJECT No:	052008
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Generalized Section Through Cover Test Plots

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	1

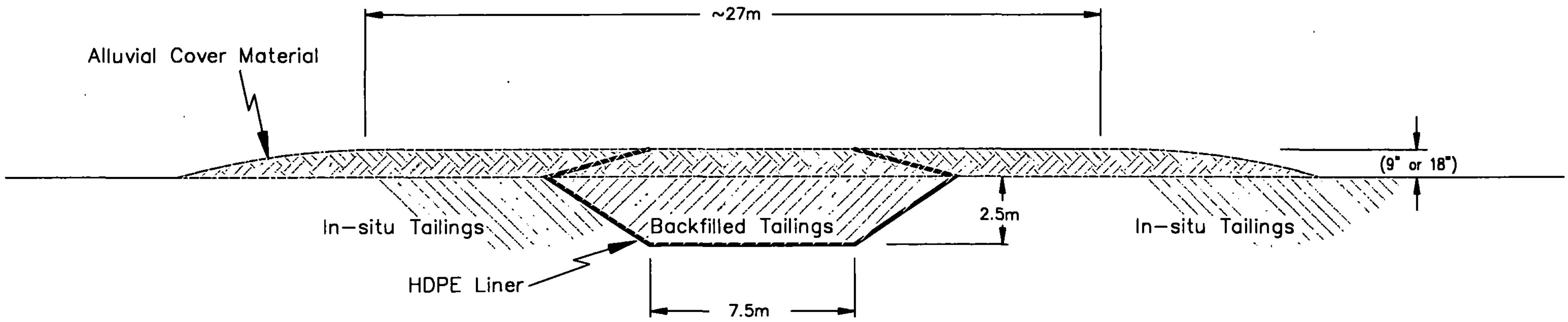


CLIENT:	MOLYCORP, INC.
PROJECT No:	052008/1
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

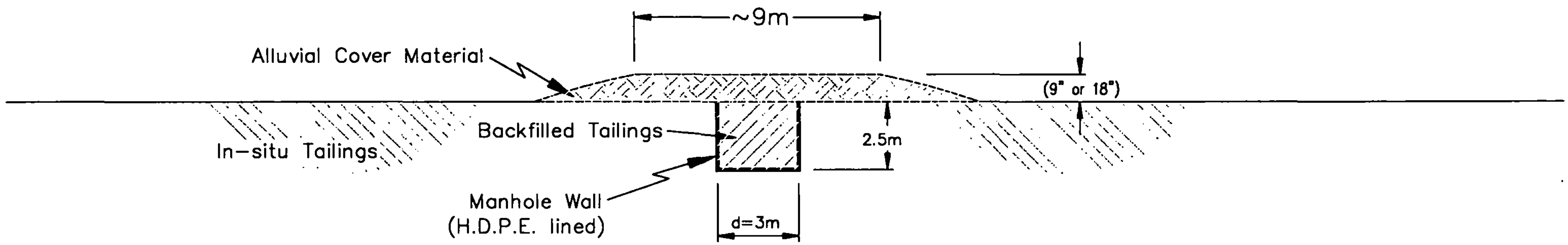
Cover Test Plots - Plan View

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	2



Option 1

Lined and Backfilled Excavation with Sloped Side Walls



Option 2

Backfilled Manhole with Vertical Side Walls

CLIENT:	MOLYCORP, INC.
PROJECT No:	052008/1
PROJECT:	QUESTA CLOSEOUT PLAN
LOCATION:	QUESTA MINE NEW MEXICO, USA

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Alternative Conceptual Designs for Lysimeter Test Plots (Cross-section)

DATE:	DRAWN BY:	FIGURE:
Jan. 2000	JG	3

Appendix A

Schedule for development of Closeout Plan for Questa Mine, New Mexico

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 1: Framework for Review & Submission of Closeout Plan for Mine Site																														
Technical Review Round 1: Characterization & Scoping																														
-TRC & MAA Planning Meeting				Jan 13-14 (projected)																										
-Background Data Summary																														
-Development Data Summary																														
-Detailed Work Plans																														
-Draft Outline of Closeout Plan																														
-Meeting									March 31 (projected)																					
Technical Review Round 2: Alternatives Evaluation																														
-Design & Assessment of Alternative Control Measures																														
-Meeting																							October 16-17 (projected)							
-Additional Design & Assessment of Alternative Control Measures																														
Initial WQA (NMED) Public Hearing on DP 1055										April 3 (projected)																				
Submission of Modified Preliminary Closure Plan to NMED																					September 29									
Technical Review Round 3: Closeout Plan Options Review																														
-Closeout Plan Options Development																														
-MAA Meeting																											December 14-15 (projected)			
-Final Closeout Plan Preparation																														
Submission of Closeout Plan																													January 31 2001	
Submission of Supplementary Report to Closeout Plan																														May 31, 2001
WQA (NMED) Public Hearing on Modification of DP 1055																														July 31, 2001 (projected)
NMMA (MMD) Public Hearing on Closeout Plan																														August 1, 2001 (projected)
Submission of Financial Assurance Proposal (MMD)																														Oct 30, 2001
NMED Determination on Closeout Plan																														Nov 30, 2001 (projected)
Public Hearing on Financial Assurance Proposal (MMD)																														Nov 30, 2001 (projected)
Anticipated Approval of Closeout Plan, Financial Assurance in place (MMD)																														Dec 31, 2001 (projected)

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 2: Work Tasks under DP1055 (Mine Site)																														
A Characterization and Monitoring																														
A.1 Waste Rock Characterization																														
Phase 1 Initial investigation																														
Task 1.1 Review of mining history and mine records and determination of dump composition																														
Task 1.2 Site reconnaissance and mapping to define all sources (natural, mine disturbed and dumps)																														
Task 1.3 Phase 1 drilling and sampling program	C																													
Task 1.4 Instrumentation and monitoring	P																													September 2001
Task 1.5 Phase 1 static and kinetic laboratory geochemical testing program	P																													September 2001
Task 1.6 Phase 1 geotechnical/geohydrological testing program																														
Task 1.7 Phase 1 characterization and monitoring analyses and report									March 17																					
Task 1.8 Preliminary design and evaluation of closure measures																														
Phase 2 Investigation and Testing Program										March 31																				
Task 2.1 Phase 2 drilling and sampling program																														
Task 2.2 Phase 2 laboratory geochemical testing program																														
Task 2.3 Phase 2 geotechnical/geohydrological testing program																														
Task 2.4 Phase 2 characterization and monitoring analyses and report																				Aug 31										
Task 2.5 Design and evaluation of closure measures (Closeout Plan)																														Jan 31 2001
A.2 Geophysical Surveys																														
Task 1 Seismic and electrical resistivity profiles in vicinity of MMW-7																				Aug 31										
A.3 Installation of Monitoring Wells																														
Task 1.1 Installation of additional monitoring wells	C																													
A.4 Infiltration of storm water runoff																														

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

			Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
	Task 1.1	Continued sampling required by Molycorp's Storm Water Pollution Prevention Plan																														ongoing
	Task 1.2	Calculation of potential impact on ground water quality by storm water runoff																														
A.5	Surface and ground water quality monitoring																															
	Task 1.1	Monthly gauging of monitoring wells																														ongoing
	Task 1.2	Bi-annually sampling and water quality analysis																														ongoing
A.6	Reporting of regular monitoring well data																															
	Task 1.1	All available gauging and water quality results from the mine monitoring wells forwarded to	C																													
A.7	Background Characterization Study																															
	Phase 1																															
	Task 1.1	Reconnaissance survey						Jan 31																								
	Task 1.2	Historical and anthropological use determination																														
	Task 1.3	Surface water monitoring																														May 2001
	Task 1.4	Report on background characterization of surface water from non-mining scar affected areas																							Oct 16							
	Phase 2							Jan 31																								
	Task 2.1	Ground water reconnaissance survey																														
	Task 2.2	Ground water quality monitoring																														May 2001
	Task 2.3	Background characterization of groundwater from non-mining scar affected areas (w/ drilling)																	Jul 17													
	Task 2.4	Reconnaissance survey of all scar areas																														
	Task 2.5	Watershed baseline contaminant load model																											Dec 15			
A.8	GSI/Water from the P-series of wells																															
	Task 1.1	Submit data	C																													

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

			Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
A.9	**Report Submittals**																															
	Task 1.1	Submit 1997 reports by TRC Environmental Solutions Inc., Schafer & Associates and Chadwick Ecological Consultants Inc.	C																													
A.10	**Water Balance for Waste Dumps**																															
	Phase 1	*Water balance for three representative dumps*																														
	Task 1.1	Select waste rock types; analyze soil characteristics; finalize design (with modeling) submit work plan for cover test plot construction	P							Feb 29																						
	Task 1.2	Install plots and met station; set-up and data acquisition system																														
	Task 1.3	Preparation of As-Built Report																June 30														
	Task 1.4	Monitoring																														
	Task 1.5	Initial review of model calibration, recommendation for changes (if required)																														
	Task 1.6	Monitoring																														June 2001
	Task 1.7	Calibration of soil-atmosphere model																							Oct 16							
	Task 1.8	Water balance calculations																														
	Phase 2	*Water balance for all dumps*																														
	Task 2.1	Water balance calculations																											Dec 15			
A.11	**Comprehensive Hydrological Balance**																															
	Phase 1	*Natural contaminated drainage site detailed hydrological balance*						Jan 31																								
	Task 1.1	Surface water characterization and model																														
	Task 1.2	Groundwater characterization and model																														
	Task 1.3	Integrated geochemical load balance																											Dec 15			
	Phase 2	*Mine detailed hydrological balance*						Jan 31																								
	Task 2.1	Surface water characterization and model																														
	Task 2.2	Groundwater characterization and model																														

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

		Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Task 2.3	Integrated geochemical load balance																											Dec 15			
Phase 3	*Tailings detailed hydrological balance(see Schedule for Tailings Facility)*																														
Phase 4	*Red River basin system description*						Jan 31																								
Task 4.1	Surface water characterization and model																														
Task 4.2	Groundwater characterization and model																														
Task 4.3	Integrated geochemical load balance																											Dec 15			
B	**Abatement of Existing Ground and Surface Water Contamination**																														
C	**Contingency Plan**																														
C.1	**Submittal of Contingency Plan**																														
Task 1.1	Submit plan (revisions to plan)	P																			Aug 31										
D	**Closure Plan and Financial Assurance Plan**																														
D.1	**Revegetation Program**																														
Task 1.1	Continue implementation and research program with Revegetation Success & Establishment Report	.																													April 2001
D.2	**Closure Plan**																														
Task 1.1	Determine what, if any additional measures are required for the Closeout Plan																						Sep 30								
D.3	**Post-Closure Hydrologic Model**																														
Task 1.1	Assess mine post-closure impacts to ground water and surface water																														
Task 1.2	Develop and refine dynamic hydrologic model																														
D.4	**Interim Financial Assurance Plan**																														
Task 1.1	Provide financial assurance plan pursuant to Water Quality Act	P				Jan 14 (projected)																									

Table A1. Schedule for development of Closeout Plan for Mine Site - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 3: Additional Studies for Close-Out Planning																														
E Additional Studies - Mine Site																														
Study E1 Surface Erosion & Stability Analysis (Work Plan, Investigation & Report)			▲ Dec 31															■ Aug 16												
Study E2 Rooting Zone and Cover Evaluation (Work Plan, Investigation & Report)					▲ Jan 31																	■ Oct 16								
Study E3 Borrow Materials Investigation (Work Plan, Investigation & Report)					▲ Jan 31																	■ Oct 16								
Study E4 Wildlife Impact Study (Work Plan, Investigation & Report)							▲ Feb 29																							■ April 2001
Study E5 Open Pit Waiver Information (Work Plan, Investigation & Report)					▲ Jan 31																									■ April 2001
Study E6 Subsidence Area Waiver Information (Work Plan, Investigation & Report)					▲ Jan 31																									■ April 2001
Study E7 Vegetation Test Plot (Work Plan)					▲ Jan 31																									

Code:

▲ Workplan C Work Task completed ——— Duration of Specified Task

■ Report P Work Task partially completed — — Duration of Specified Task (weather permitting)

● Projected Meeting/Hearing

Note: Work Plan and report submittal dates are the dates of first submittal by Molycorp. It is assumed that no more than one month will be required after submittal for workplan or report acceptance.

Table A2. Schedule for development of Closeout Plan for Tailings Facility - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Part 1: Framework for Review & Submission of Closeout Plan for Tailings Facility																														
Questa Tailings Facility Revised Closure Plan submitted		**May 1, 1998**																												
WQA (NMED) Public Hearing on DP 933 Modification																		**July 31, 2000 (projected)**												
NMMA (MMD) Public Hearing on Tailings Closeout Plan																		**Aug 1, 2000 (projected)**												
NMED Determination on Closeout Plan																										**Nov 30, 2000 (projected)**				
Submission of Financial Assurance Proposal (MMD)																					**Sep 29, 2000 (projected)**									
Public Hearing on Financial Assurance Proposal (MMD)																									**Nov 15, 2000 (projected)**					
Anticipated Approval of Closeout Plan, Financial Assurance in place (MMD)																												**Dec 29, 2000 (projected)**		
Part 2: Work Tasks under DP1055																														
A Characterization and Monitoring																														
A.11 Comprehensive Hydrological Balance																														
Phase 3 Tailings detailed hydrological balance						**Jan 31**																								
Task 3.1 Surface water characterization and model	P																													
Task 3.2 Groundwater characterization and model	P																													
Task 3.3 Integrated geochemical load balance	P													May 31																
Part 3: Work Tasks under DP 933 (Tailings Facility)																														
A Characterization and Monitoring																														
Task A1 Tailings Revegetation (Work Plan, Investigation & Report)								Feb 29																						April 2001

Table A2. Schedule for development of Closeout Plan for Tailings Facility - Questa Mine, New Mexico.

	Completed	01-Dec-99	15-Dec-99	01-Jan-00	15-Jan-00	01-Feb-00	15-Feb-00	01-Mar-00	15-Mar-00	01-Apr-00	15-Apr-00	01-May-00	15-May-00	01-Jun-00	15-Jun-00	01-Jul-00	15-Jul-00	01-Aug-00	15-Aug-00	01-Sep-00	15-Sep-00	01-Oct-00	15-Oct-00	01-Nov-00	15-Nov-00	01-Dec-00	15-Dec-00	01-Jan-01	15-Jan-01	projected date of completion (if after January 31, 2001)
Task A2 Tailings Cover Test Plot Study (Work Plan, Investigation & Report)						Jan 31																								June 2001
Part 4: Additional Studies for Close-Out Planning																														
B Additional Studies - Tailings																														
Study B1 Surface Erosion & Stability Analysis (Work Plan, Investigation & Report)				Dec 31										May 31																
Study B2 Borrow Materials Investigation (Work Plan, Investigation & Report)						Jan 31								May 31																
Study B3 Wildlife Impact Study (Work Plan, Investigation & Report)								Feb 29						May 31																

Code:

- ▲ Workplan
- ■ Report
- ● Projected Meeting/Hearing
- C Work Task completed
- P Work Task partially completed
- ——— Duration of Specified Task
- — — Duration of Specified Task (weather permitting)

Note: Work Plan and report submittal dates are the dates of first submittal by Molycorp. It is assumed that no more than one month will be required after submittal for workplan or report acceptance.

Appendix B

Maintenance of Field Performance Monitoring System

Appendix B

Maintenance of Field Performance Monitoring System

Record general observations of the instrumentation areas as well as weather conditions and the date that maintenance occurs in a maintenance log book.

The following items are also required but will not necessarily be used each time maintenance is conducted:

- tweezers,
- camel hair brush,
- filters for Bowen Ratio System air intakes,
- spare domes for the net radiometers,
- spare desiccant tubes for the net radiometers,
- spare desiccant packs for the datalogger enclosures,
- plastic bottle (with spray spout) of mild HCL acid,
- plastic bottle (with spray spout) of distilled water,
- small flat head screw driver (should be kept in each of the datalogger enclosures),
- allon key tool for tipping bucket rain gauge,
- tissue paper,
- plastic bottle (with spray spout) of a mixture of 40% methanol alcohol and 60% distilled water, and
- a 2m or similar step ladder.

Bowen Ration Station:

Please refer to the Bowen Ratio Maintenance document.

Weather Station:

Maintenance of the Weather Station and its components should be conducted every time data is collected from the Weather Station datalogger.

Fibreglass Enclosure

1. Check the colour of the humidity indicator on the inside of the enclosure box. Three dots indicate warnings and action required.

2. Remove the two desiccant packs as required.

3. The desiccant packs can be recycled by following the instructions on the packs.

Net Radiometer

1. Condensation inside the windshields may indicate a leak.

2. Cracking or crazing of the windshields usually appears first along the base.

3. Clean radiometer windshields using paper tissue and distilled water (coarse paper or cloth will scratch the windshields and should be avoided)

4. Replace the windshields if they are cracked or opaque (usually required every 3-6 months).

5. Please refer to the Q-7.1 manual for the procedure to replace the windshields

6. Check radiometer level and adjust as required.

7. Condensation within the windshields may be a result of wet silica gel. Inspect the silica gel within the desiccant tube at the end of the sensor opposite to the windshields to ensure it is blue and white. If the colour changes to pink and white the silica gel will need to be replaced with dry silica gel. Wet silica gel can be dried by removing it from the desiccant tube and baking at 130°C until it returns to the blue and white colour.

8. Please refer to the Q-7.1 manual for the procedure to replace the desiccant tubes.

9. Condensation within the windshields may also be a result of poor o-ring sealing and cracked windshields.

10. Calibration can be checked by comparing sensor readings to a second similar sensor.

Tipping Bucket Rain Gauge

1. Remove the tipping bucket housing by loosening the 3 screws along the base of the rain gauge using an allon key wrench. The screws do not have to be completely removed for the housing to be removed.

2. Remove debris, insects, sediments, etc. from the collection funnel, debris screen, siphoning mechanism, or tipping bucket assembly.

3. Verify the tipping bucket moves freely.

4. Make a note in the maintenance log book of the number of tips that occurred during maintenance.

5. Check that the base of the rain gauge is level using the bullseye level

6. Adjust the level using the 3 levelling screws connected to the mounting plate as required.

7. The rain gauge is factory calibrated; re-calibration is not required unless damage has occurred or the adjustment screws have loosened.

8. A calibration check will be performed by O'Kane Consultants Inc. during site visits.

Wind Monitor:

1. Ensure the wind monitor is level by viewing sensor from the ground.

Temperature and Relative Humidity Probe:

1. Remove debris from radiation shield.

2. Remove probe and check the condition of the black screen the probe end.

3. Remove the black screen and check to ensure that a build up of salt on the sensor has not occurred. This will not be likely in the arid climate. However, gently rinse the sensor with distilled water if required.

END

Appendix C

Maintenance of Bowen Ratio System

Appendix C

Bowen Ratio Station Maintenance

Maintenance is very important for the Bowen system in order to obtain good quality data. Therefore, it is paramount that the maintenance occur at least every 2 weeks. The Bowen system will only operate during the spring, summer and fall.

General:

1. Change air intake filters every 1 - 2 weeks.

2. Clean mirror and adjust bias every 1 - 2 weeks.

3. Clean thermocouples when data is downloaded, or as required.

4. Clean radiometer domes and check radiometer level when data is downloaded, or as required.

5. The two valves for the pump should be set at 0.4 litres per minute.

Setting Flags:

The following steps are required to get the LCD screen on the 21X datalogger to the proper location within the program so that maintenance flags can be set high or low.

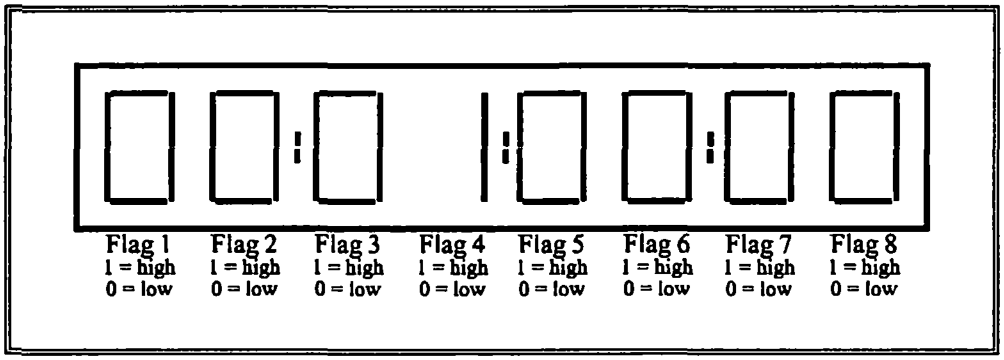
1. Press: *

2. Press: 6

3. Press: A

4. Press: D

The 21X LCD screen should now look like:



In the above example flag 4 is high and all other flags are low. Touch the number on the key pad that you want to set the flag high or low. For example: to set flag 6 high, touch number 6 on the key pad and a 1 will be replaced by the 0 on the 21X LCD screen to indicate that flag 6 has been set high.

Filters:

1. Filters are Teflon, 25 mm diameter with a 1 micro meter pore size (i.e. Nuclepore 130610 or Gelman 66154).

2. Before removing filters (upper and lower) *set flag 7 high* to turn the pump/mirror off. It will take anywhere from less than one second and up to 10 seconds for the pump to turn off once flag 7 as been set high. The program automatically sets flag 7 low once the pump is turned off.

3. Before removing filters *set flag 4 high* to disable averaging.

4. Install the clean filters with the glossy, textured side down. Remove any protection paper (blue) from the filter.

Thermocouples:

1. Before cleaning the thermocouples ensure the pump/mirror is off (i.e. flag 7 has already been set high as a result of filter paper maintenance).

2. Remove all debris from the thermocouples using a camel hair brush and tweezers.

3. The thermocouples can be dipped in a mild muratic (hydrochloric acid) to dissolve spider webs.

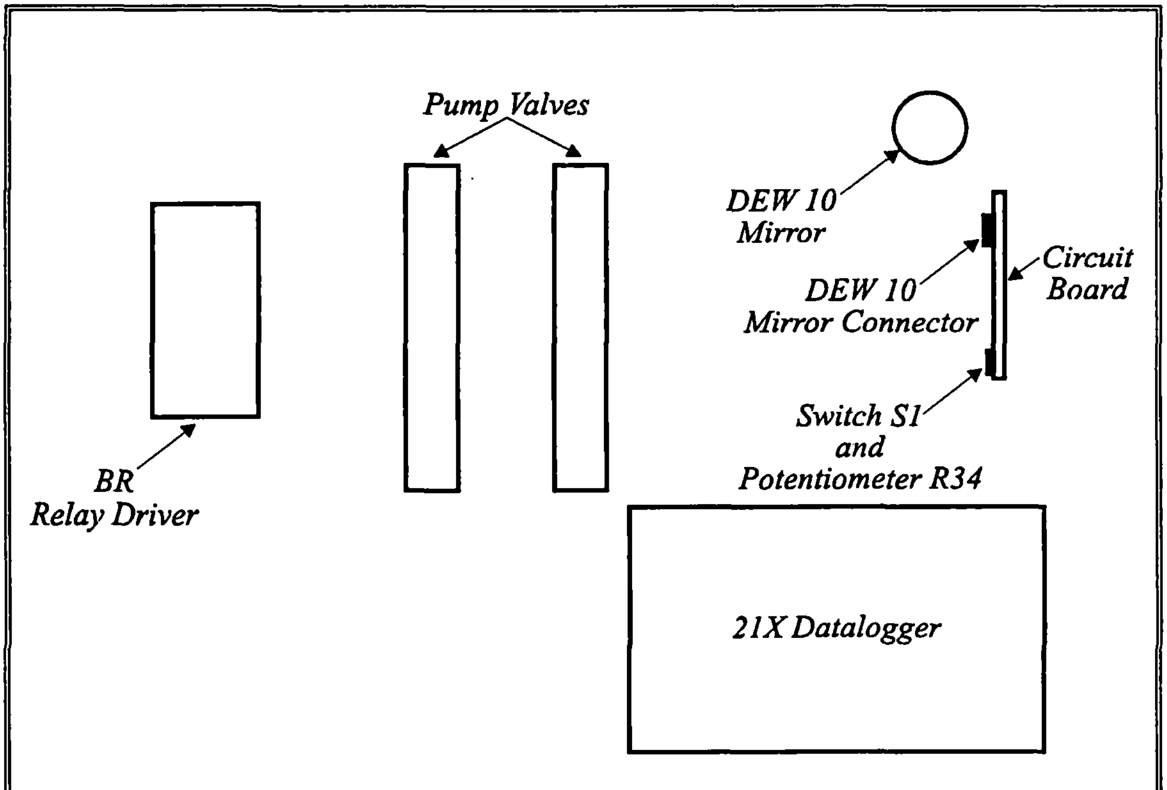
4. Rinse the thermocouples thoroughly with distilled water after dipping in acid.

5. *Set flag 6 high* to activate the pump/mirror when maintenance is complete. It will take anywhere from less than one second and up to 10 seconds for the pump to turn on once flag 6 as been set high. The program automatically sets flag 6 low once the pump is turned on.

Cleaning the Dew 10 Mirror:

Mirror cleaning and optical bias adjustments are important maintenance functions. Proper adjustment of the bias is essential.

1. Refer to the diagram below (or on the inside of the door of the white fibreglass enclosure) to locate the components discussed below.



Schematic of Bowen Ratio System Enclosure Layout

2. Ensure that Bowen Ratio processing is stopped by checking that flag 4 is high.

3. Shut off the thermoelectric cooler by sliding switch S1 towards the nearest end of the circuit board, out of the operating position (OP) and into the balance position (BAL).

4. Remove the DEW 10 connector from the circuit board. Pull firmly on the DEW 10 mirror until it slides out of the mirror block.

5. Locate the mirror, it is circular in shape and only the edge of it can be seen when looking straight into the mirror cavity. The mirror is mounted on a 45° angle within the mirror cavity.

6. Clean the mirror with a cotton bud. Distilled water or a mixture of 40% methanol alcohol and 60% distilled water may be used as the cleaning solution. Remove any excess cleaning fluid with a clean dry bud. Wait at least 2 minutes before continuing to the next step. This will allow sufficient evaporation of moisture from the mirror.

7. Place the DEW 10 mirror back into the chilled mirror block and reconnect it to the circuit board. Twist the DEW 10 mirror 1/8 of a turn while firmly pushing it into the mirror block to aid in reinserting the DEW 10. Be sure that the mirror cavity is parallel to the flow through the mirror block, i.e. vertical.

8. Use a small screwdriver to turn the potentiometer, R34, located on the bottom edge of the circuit board. If the red LED is on, turn the screw counter clockwise until the LED turns off. If the LED is not already on, turn the potentiometer clockwise until it turns on and then counter clockwise until it goes off. Now, slowly turn the potentiometer clockwise until the LED comes on again.

9. Return the switch, S1, to the normal operating position (OP). The red LED will turn off several seconds after the switch is moved to the normal operating position.

10. *Set flag 4 low* to resume the Bowen Ratio processing.

11. Cleaning the mirror with a cotton bud does not result in a surface condition like the one reached after evaporation of a dew layer. Therefore, a more appropriate bias adjustment is reached with a mirror surface on which a dew layer has been formed and then evaporated. A more appropriate bias adjustment can be made and the period between mirror cleaning can be extended by adding 2 steps to the procedure outlined above.

These additional steps are:

11. Allow the system to run under normal operation for 8 to 24 hours after completing steps 1 - 9.

12. Now repeat steps 1, 2 and 7 through 9.

END